U. S. FOREST SERVICE

RESEARCH NOTE NC-9

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

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Forest Floor Fuels in Red and Jack Pine Stands

An investigation to determine the quantity and density of forest floor fuels in red pine (*Pinus resinosa* Ait.) and jack pine (*Pinus banksiana* Lamb.) stands was conducted on National Forests in Michigan and Minnesota. The study was designed to answer three questions:

How much fuel per acre exists in individual layers of the forest floor?

How reliably can weight of forest floor fuels be estimated from specific stand characteristics?

What is the density of individual layers of the forest floor?

In 1963, Dieterich[1] published information on weight and density of litter fuels in red pine plantations for the Lake States. This Note covers fuels in jack pine plantations and natural red pine stands.

Study procedures. — During 1963, nine red pine stands and five jack pine plantations with the following characteristics were selected for study:

	Red pine	*Jack pine*
Site index	59-69	56-65
Age, years	21-180	15-43
Basal area per acre, sq. ft.	85-195	90-170

Thirteen 1/10-acre plots were randomly located in red pine stands and 10 in the jack pine plantations. On each plot, forest floor fuels were collected from ten 1-foot-square subsamples systematically placed along the plot diagonals.

Samples of the *L*, *F*, and *H* layers of the forest floor were collected separately, ovendried, and weighed. The *L* or litter layer, consisting of undecomposed litterfall, was separated into needle, branchwood, herbaceous vegetation, and miscellaneous components. Average composition of the *L* layer on an ovendry weight basis for all plots was as follows:

	Red Pine (percent)	*Jack pine* (percent)
Needles	55	40
Branches	20	45
Herbaceous and miscellaneous vegetation	25	15

The *F* layer, containing partially decomposed material often lightly bound by fungal mycelium (fig. 1), was fairly simple to distinguish from the *L* layer.

The *H* layer, composed primarily of amorphous organic matter, was poorly developed in the sampled plantations, whereas it was clearly defined in the natural stands. Samples of humus 8 to 10 grams in dry weight were incinerated in a muffle furnace. Results indicated that less than 3 percent of the entire forest floor consisted of mineral matter. Fuel weights reported here were not adjusted for this small amount of mineral matter.

Thickness of the forest floor was measured with a small wood frame, 1 inch wide and 8 inches long, which held a sliding rule. The frame, placed at the top of each layer,

[1] *Dieterich, J. H. Litter fuels in red pine plantations. U.S. Forest Serv. Res. Note LS-14, 3 pp. 1963. (Lake States Forest Exp. Sta., St. Paul, Minn.)*

FIGURE 1. — The forest floor in this natural red pine stand, 65 years of age with site index of 60 and basal area of 190 square feet per acre, contained 6,700 pounds of material in the *L* layer and 20,300 pounds in the *F* and *H* layers together per acre.

provided an upper reference mark; and the rule, lowered to the top of the next lowest layer, provided a lower reference mark for the layer being measured. Thickness of each layer was measured 10 to 20 times per plot, depending upon its variability in individual stands. This provided an estimate of average thickness with a standard error of less than 10 percent of the mean.

Fuel weight per acre. — Weight of forest floor material per acre was extremely variable in natural red pine stands but considerably less variable in jack pine plantations as shown in the following tabulation:

	Pounds per acre, dry weight	
	Red pine	*Jack pine*
L layer:		
Average	5,600	3,400
Range	2,900-9,800	2,300-6,600
Total forest floor:		
Average	32,800	23,420
Range	10,800-74,600	17,400-30,200

Regression analyses of total forest floor weight per acre on age of stand, site index, basal area per acre, and number of trees per acre showed no significant relationships (at the 0.05 level). A history of erratic fire occurrence in the natural red pine stands may have obscured relationships and increased variability of forest floor weights under given stand conditions. On the other hand, red pine *plantations* show *less* variability in stand characteristics and forest floor fuel weights than do jack pine plantations. Dieterich's work in red pine plantations showed good correlation ($r^2 = 0.796$) between basal area per acre and forest floor weight.[2] Most of the plantations he studied were 15 to 25 years of age, on good sites, and had never been burned. Although the sampling procedures used in jack pine plantations were similar to those used by Dieterich, the relationship of fuel weight to basal area was not as strong in jack pine as it was in red pine. Perhaps a larger sample of jack pine plantations would reveal a stronger correlation.

Predictions of forest floor fuel weight from stand characteristics are most dependable in stands having uniform structure, a history of no fire, and an origin on other than old forest floor material. Plantations approach these requirements. Estimates in natural stands, which frequently originate on existing forest floor material and may have been modified by fire, would tend to be less reliable.

Density of forest floor. — Density was computed from volume and weight per acre of each layer. Volume of each layer was determined from average thickness and contains both solid material and void space. The litter layer in jack pine plantations was about twice as dense as in red pine plantations and natural stands (table 1). Also, the litter layers of both species were less dense than their corresponding *F* and *H* layers.

Density, expressed as pounds per acre-inch, partially reflects the spacing between individual fuel particles and is a rough measure of fuel bed compactness. The large difference in density between litter layers of jack pine and red pine is due to differences in the physical characteristics of their needles. Fallen red pine needles are long and curved and form a loose litter layer. Jack pine needles

[2] *Dieterich, 1963. See footnote 1.*

TABLE 1. — *Density and thickness of layers of the forest floor from red pine and jack pine stands in the Lake States*

Forest floor layer	Red pine				Jack pine	
	Plantations[1]		Natural stands		Plantations	
	Density	Thickness	Density	Thickness	Density	Thickness
	Lb./ac.-in.[2]	Inches	Lbs./ac.-in.[2]	Inches	Lbs./ac.-in.[2]	Inches
L	7,000	0.7	9,000	0.6	17,700	0.2
F and H	11,600	.6	15,700	1.5	22,200	.9
Total	9,300	1.3	13,400	2.1	20,900	1.1

[1] From Dieterich, 1963; see footnote 1 of text.

[2] Some expressions of fuel density found in fire research literature have been in terms of pounds per cubic foot of fuel (solids and voids). Density expressed by pounds per acre-inch, when multiplied by 2.75×10^{-4}, can be converted to pounds per cubic foot.

are short and form a more compacted litter layer than red pine needles.

Compared to jack pine, the less compact red pine litter contains more free air space between needles. As a result, air movement is less restricted. This indicates that the drying rate and potential combustion rate of red pine litter is higher than that of jack pine litter.

The forest floor plays an important role as a source of fuel for both wildfires and prescribed burns. Eventually, fuel weight determinations may be used in combination with other fuel properties such as moisture content, particle size, and compactness to predict fire behavior with operable precision.

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